DT04 Rec'd PCT/PTO 07 JUL 2004

COLD-FORMED STEEL JOISTS

FIELD OF THE INVENTION

The present invention relates to lightweight frame construction for residential and commercial buildings. The present invention has particular applicability to the manufacture of lightweight open web truss girders used in roof and floor applications in building construction.

BACKGROUND ART

Roof and floor structures employing lightweight prefabricated steel trusses are commonly used in low-rise buildings with all types of end uses, including residential and commercial uses. Structures made from steel trusses are well suited for the support of uniformly distributed roof or floor loads, suspended ceilings, ducts, sprinklers and lights. As a roof or floor joist, typical lightweight steel structural members are adapted to be secured to wall constructions of a variety of building systems, including masonry, concrete, wood, steel or other supporting members.

Fabrication and use of steel trusses, such as open web joists, for construction dates from the mid-nineteenth century. Starting at the beginning of the twentieth century, steel joists were produced to individual manufacturer's patents and standards. Chords for these conventional open web steel joists typically comprise hot-rolled steel shapes cut to length, and the web members comprise round steel rod. Disadvantageously, when mill run lengths are cut to match lengths required for particular applications, either a high rate of scrap results, or additional welded splices are made to the chords during fabrication, thereby increasing the required labor and handling.

Furthermore, the span of conventional joists is limited, requiring supporting structures, such as rafters, to be spaced closer than is desirable.

There exists a need for a lightweight prefabricated steel truss that can be efficiently manufactured and is able to span larger distances than conventional joists.

SUMMARY OF THE INVENTION

An advantage of the present invention is a cold-formed joist that can span a distance of up to 100 feet, and is economically manufactured.

According to the present invention, the foregoing and other advantages are achieved in part by a joist having a first chord, the first chord having a length and a cross-section substantially symmetrical about a center line. The first chord cross-section comprises a horizontal base having two ends, and a pair of downwardly extending legs. Each leg comprises a chamfered portion extending downward and outward from one end of the base at an acute angle to the horizontal; an upper vertical portion, perpendicular to the base, extending downward from a lower end of the chamfered portion; an inwardly recessed portion, parallel to the base, extending towards the center line from a lower end of the upper vertical portion; and an attachment portion, perpendicular to the base, extending downward from an inner end of the inwardly recessed portion. The attachment portions of the legs define an opening for receiving a web of the joist, the opening extending substantially the entire length of the first chord.

Another aspect of the present invention is a seat member for attaching the joist to a structural member, the seat member having a pair of opposed vertical walls for fitting in the opening and abutting the chord attachment portions, a notch disposed such that the seat member is rigidly attachable to the attachment portions and to one of the web members, and a pair of flanges for attachment to the structural member.

A still further aspect of the present invention is method of assembling a joist, the method comprising providing an elongated joist chord with a cross-section having a center line and including a substantially horizontal base, a pair of substantially vertical side walls whose top ends are attached to the top wall, a pair of lower horizontal walls extending inward from the bottom ends of the side walls towards the center line of the chord cross-section, and a pair of vertical attachment portions extending downward from the inward-extending ends of the lower horizontal walls; rigidly assembling a web member having a pair of opposed walls spaced to fit between and abut the pair of attachment portions to the chord such that the attachment portions abut the web member opposed walls; and welding each of the web member walls to a respective one of the attachment portions without moving the web member/chord assembly, while the assembly is in a flat position.

Additional advantages of the present invention will become readily apparent to those skilled in this art from the following detailed description, wherein only the preferred embodiment of the present invention is shown and described, simply by way of illustration of the best mode contemplated for carrying out the present invention. As will be realized, the present invention is capable of other and different embodiments and its several details are capable of modifications in various obvious respects, all without departing from the invention. Accordingly, the drawings and description are to be regarded as illustrative in nature, and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

Reference is made to the attached drawings, wherein elements having the same reference numeral designations represent like elements throughout, and wherein:

Figure 1 is an elevational view of a joist in accordance with an embodiment of the present invention.

Figure 2A is a cross-sectional view of a joist chord according to an embodiment of the present invention.

Figure 2B is a perspective view of the chord of Figure 2A.

Figure 3A is a cross-sectional view of a web member used in the joist of an embodiment of the present invention.

Figure 3B is a perspective view of a portion of a joist according to an embodiment of the present invention.

Figure 4A is a cross-sectional view of a chord according to an embodiment of the present invention.

Figure 4B is a cross-sectional view of a web member used in conjunction with the chord of Figure 4A.

Figure 5A is a cross-sectional view of a chord according to an embodiment of the present invention.

Figure 5B is a cross-sectional view of a web member used in conjunction with the chord of Figure 5A.

Figure 6A is a cross-sectional view of a chord according to an embodiment of the present invention.

Figure 6B is a cross-sectional view of a web member used in conjunction with the chord of Figure 6A.

Figure 7A is a cross-sectional view of a chord according to an embodiment of the present invention.

Figure 7B is a cross-sectional view of a web member used in conjunction with the chord of Figure 7A.

Figure 8A is a cross-sectional view of a chord according to an embodiment of the present invention.

Figure 8B is a cross-sectional view of a web member used in conjunction with the chord of Figure 8A.

Figures 9A-9C are side elevational views of truss configurations of the joists of several embodiments of the present invention.

Figure 10A is a side elevational view of a seat according to an embodiment of the present invention.

Figure 10B is a front elevational view of a seat according to an embodiment of the present invention.

Figure 10C is a side perspective view of a portion of a joist according to an embodiment of the present invention.

Figure 10D is a bottom perspective view of a portion of a joist according to an embodiment of the present invention.

Figures 11A and 11B are side and front elevational views, respectively, of a portion of a joist according to an embodiment of the present invention.

Figure 11C is a cross-sectional view of the joist of Figure 11A.

Figure 12 is a perspective view of a joist according to an embodiment of the present invention.

DESCRIPTION OF THE INVENTION

The joists of the present invention offer advantages over conventional open web bar joists because they are fabricated entirely of cold-formed steel components, made by running a coil of sheet steel through a series of rollers, each of which progressively bends the sheet to

its final form. The use of cold-formed components provides manufacturing economies in reduced scrap and lower shop labor. It also provides field erection economies in a more rigid member to hoist to the roof during erection, easier field bolting to supporting framing, and easier installation of modern self-drilling fasteners than conventional open web steel bar joist.

The open web cold-formed metallic joists of the present invention comprise cold-formed top and bottom chords and cold-formed metallic truss web members arranged in a vertical and diagonal fashion. The truss web members are shop welded to the chords. End connections, or "seats" are each shop welded to the top chord and to one of the webs. Each seat comprises a pair of vertical metallic planes that act as shear plates, welded to and extending outwardly and upwardly of the end portion of the top chord of the joist, and portions extending horizontally either side of the chord and punched with holes for easy field bolting to beams or other supporting elements. Each of the chords of the inventive joist comprises a planar base and a pair of legs. Each leg comprises a chamfered portion extending downward and outward from one edge of the base at an acute angle θ to the horizontal; e.g., about 45 degrees, for stiffening the longitudinal edges of the base, to accommodate axial and moment forces. An upper vertical portion, perpendicular to the base, extends downward from a lower end of the chamfered portion to provide a planar width of material to accommodate axial and moment forces. An inwardly recessed portion parallel to the base extends towards the chord's center line from a lower end of the upper vertical portion; and an attachment portion, perpendicular to the base, extends downward from an inner end of the inwardly recessed portion. The inventive chord imparts the joist of the present invention with enough stiffness to span up to 100-foot lengths.

Custom made-to-order cold-formed joists according to the present invention are fabricated in the most economical configuration to resist minimum specified loads including

self weight, floor loads for a mezzanine floor application, collateral loads (e.g., suspended ceilings), sprinklers, and naturally occurring loads such as snow and wind uplift. In addition, custom made-to-order cold-formed joists are sized to withstand compression when acting as struts in the overall wind-bracing scheme for the building.

An embodiment of the present invention will now be described with reference to Figs. 1, 2A and 2B. As shown in Fig. 1, a joist 100 according to the present invention comprises two chords 200 having identical cross sections, the upper chord 200 having a length L_1 and the inverted bottom chord 200 having a length L_2. Chords 200 are joined by a series of regularly spaced web members 300. Joist 100 is for use in residential and commercial structures requiring a roof or floor truss having a span of up to about 100 feet.

One of the chords 200 is shown in detail in Figs. 2A-B. Chord 200 has a cross-section substantially symmetrical about a center line CL. The chord cross-section comprises a horizontal base 205 having two ends 205a, 205b, and a pair of downwardly extending legs 210. Each leg 210 comprises a chamfered portion 210a for stiffening the longitudinal edges 205a, 205b of base 205, to accommodate axial and moment forces. The chamfered portions 210a extend downward and outward from one edge of base 205 at an acute angle θ to the horizontal; e.g., about 45 degrees. An upper vertical portion 210b, perpendicular to base 205, extends downward from a lower end of chamfered portion 210a to provide a planar width of material to accommodate axial and moment forces. An inwardly recessed portion 210c, parallel to base 205, extends towards center line CL from a lower end of upper vertical portion 210b; and an attachment portion 210d, perpendicular to base 205, extends downward from an inner end of inwardly recessed portion 210c. Base 205 and leg portions 210a-d are substantially planar throughout the entire length L of chord 200.

Attachment portions 210d define an opening 215 for receiving webs 300 of joist 100, the opening 215 extending substantially the entire length L of chord 200. Base 205 has a width W1, and opening 215 has a width W2, and W1 is greater than W2. In one embodiment of the present invention, the ratio of W1 to W2 is about 1.3 to 1. A distance D between the upper vertical portions 210b of legs 210 is about twice the vertical distance d between base 205 and the inwardly recessed portions 210c of legs 210, and distance D between the upper vertical portions 210b is greater than an overall vertical height H of legs 210.

Chords 200 are shaped by a conventional cold-form process, such as a rolling process, and may be made of any appropriate metallic material such as aluminum, steel or other metal or metal alloys. In certain embodiments of the present invention, chords 200 comprise high-strength steel in the thickness range of 20-gage to 7-gage meeting the material specification ASTM A1011 SS Grade 55 or ASTM A1011 HSLAS Grade 55 Class 1, as rolled, not oiled. These materials include a range of ultimate yield strength from 30 ksi to 80 ksi. In many instances it is desirable to provide the metallic chord with a protective coating. The protective coating may be metallic or non-metallic such as paint, epoxy, or the like.

Those skilled in the art will appreciate that the dimensions of base 205 and legs 210, including the thickness of these members, are chosen to suit the load-bearing requirements of the joist in which they are used. For example, the width of base 205 can range from 1 inch for 20-gage material thickness to 5 inches for 7-gage material thickness. Opening 215 can range from ¾ in for 20-gage material thickness to 3 5/8 inches for 7-gage material. The overall vertical height H of chord 200 can range from 1 3/8 inch for 20-gage material thickness to 7 inches for 7-gage material thickness. The length of attachment portions 210d can range from 1/2 inch for 20-gage material thickness to 2 ½ inches for 7-gage material thickness. The length of upper vertical portions 210b can range from ½ inch for 20-gage

material thickness to 2 ½ inches for 7-gage material thickness. Exemplary embodiments of the inventive chord are illustrated in Figs. 4A, 5A, 6A, 7A, and 8A, showing relevant dimensions.

The joist 100 of the present invention (see Fig. 1) comprises a plurality of conventional cold-formed steel web members 300 between the chords 200. Referring now to Fig. 3A, each web 300 has a pair of opposed vertical walls 310 for fitting in the opening 215 of chords 200. Those skilled in the art will appreciate that the dimensions of walls 310 and the thickness of web members 300 are chosen to suit the load-bearing requirements of the joist in which they are used. Exemplary webs 300 used with the embodiments of the inventive chord 200 illustrated in Figs. 4A, 5A, 6A, 7A, and 8A are shown in Figs. 4B, 5B, 6B, 7B, and 8B, respectively, along with relevant dimensions.

As shown in Fig. 3B, which is a detail of joist 100, one end of each web 300 is rigidly attached to a first one of chord 200 at attachment portions 210d, as by welding. Referring again to Fig. 1, joist 100 further comprises a second one of chord 200, substantially identical to the first one of chord 200 and disposed substantially parallel to the first one of chord 200. A second end of each web 300 is rigidly attached to the second one of chord 200 at the second chord's attachment portions 210d, as by welding.

In some embodiments of the present invention, at least one of the webs 300 is attached to a chord 200 at about a 45-degree angle to the longitudinal axis of chord 200, as shown in Fig. 1. In further embodiments of the present invention, this angle varies from about 30 degrees to about 60 degrees. In some embodiments of the present invention, at least one of webs 300 is attached to a chord 200 perpendicular to the longitudinal axis of the chord, as also shown in Fig. 1. Although the depth of joist 100 is shown as 27 inches in Fig. 1, those skilled in the art will appreciate that the joist depth can vary from about 15 inches to about 72

inches, as required. In certain embodiments of the present invention, chords 200 and webs 300 are attached to each other to form a joist comprising a conventional Warren truss structure, as shown in Fig. 9A, a modified Warren truss (including additional webs represented by dotted lines in Fig. 9A), a conventional Pratt truss, as shown in Fig. 9B, or a conventional Howe truss, as shown in Fig. 9C.

In a further embodiment of the present invention shown in Figs. 10A-D, joist 100 comprises a cold-formed seat member 1000 for attaching the joist to a supporting member (not shown) such as a masonry, concrete, wood or steel supporting member. Seat 1000 is readily pre-fabricated in the shop, as by laser-cutting sheet steel and die stamping, thus requiring only field bolting to complete the connection of joist 100 to beams or other supporting elements. Referring now to Figs. 10A-B, which include dimensions to illustrate a seat 1000 of an exemplary embodiment of the present invention, seat 1000 has a pair of opposed vertical walls 1010 for fitting in the opening 215 of chord 200 and abutting the chord attachment portions 210d, and a notch 1020 disposed. Seat 1000 is rigidly attachable to attachment portions 210d and to one of the web members 300, as by welding, such that vertical walls 1010 act as shear plates. A pair of flanges 1030 extend horizontally for attachment to the structural member (see Figs. 10C-D). Flanges 1030 have through-holes 1031 for field bolting to beams or other supporting elements. When welded to the cold-form metallic chord 200, cold-formed seat 1000 and chord 200 act as a composite, resulting in economies due to savings in material that would be required for the chord or seat acting alone.

In an alternative embodiment of the present invention, a cutback of the top chord 200 provides clearance for field assembly and enables holes 1031 in seat 1000 to be accessed with a conventional spud wrench for alignment, and a conventional socket wrench for tightening a

fastener from the top. Referring now to Fig. 12, seat 1000 has a seat width A, and the top chord 200 is cut back a distance B to for easy access to through holes 1031, and to enable alignment and tightening of nut 1210 and bolt 1220 to secure seat 1000 to a rafter 1230. In one exemplary embodiment of the present invention, seat width A is 6.75 inches, and the top chord 200 is cut back a distance B of 1/4" from the end of the seat. Each seat 1000 is cut back ¼" from the centerline of rafter 1230, resulting in a gap of about 1/2" between joist chords at rafter 1230. After seat 1000 is secured to rafter 1230, a conventional cover plate (not shown) can be installed with screws to provide support for roof panel screws or standing seam clip screws, as needed for attachment of a conventional roof panel or roof panel clip.

A method of producing the joist of the present invention will now be described. The method generally comprises roll-forming the chords 200, roll forming the open channel web members 300, laser cutting and die-forming the end connection seats 1000, inserting web members 300 and seats 1000 between the attachment portions 210d of top and bottom chord members 200, and fusion welding web members 300 and seats 1000 to the chords 200.

Web members 300 and seats 1000 are welded to chords 200 using fillet welds in either lap or T joints. Fillet welds are sized to transfer internal forces between the web and chord members. The fillet welds are made using electrodes with about 70 ksi tensile strength. The weld geometry and weld strength can be achieved employing conventional welding processes. One such process is gas metal arc welding (GMAW). In an exemplary embodiment, GMAW is conducted with.045" diameter ER70-S6 wire, a shielding gas consisting of about 90% Argon and 10% $C0_2$ at a flow rate of about 18 liters/min, an average wire speed of about 10.5 meters/min, average 25.5 volts and a travel speed of about 140 cm/min. Those skilled in the art will realize that other welding procedures could be used to achieve the same weld size and/or strength.

To improve fabrication efficiency and quality, in the inventive method all web-to-chord and seat-to-chord welds are made without turning the joist during welding. Chord, web and seat dimensions, and joint details enable all welding to be performed from one side only. Therefore, turning the assembly for welding from the opposite side is not required. All welds of the web members and seats to the chords are made in a "flat" or horizontal position; that is, while the assembly is on its side. Since the assembly is welded in the flat and from one side only, all welds can be made from above, in the shortest time and with the highest quality, as compared to prior art assembly techniques that require moving the assembly and welding the assembly in a vertical position, and/or welding the assembly from below ("overhead" welding). Vertical and overhead welding are disadvantageous in that both techniques are slower than welding in the flat from above, and weld quality is difficult to maintain.

Referring now to Figs. 11A-C, where only one chord 200 is shown for clarity, web members 300 are rigidly assembled to chords 200 such that the opposing side walls 310 of web 300 abut the attachment portions 210d of chords 200. It should be appreciated that, in practicing the present methodology, two chords 200 are assembled to webs 300 to form joist 100 as described hereinabove and shown in Fig. 1 prior to welding. Camber, defined as curvature of a flexural member in the plane of loading, is conventionally applied to steel joists to prevent sagging under load. In the present methodology, upward camber is induced during assembly and prior to welding, at a ratio of approximately 1 inch per 50 ft. of joist length. Web members 300 are welded to chords 200 with approximately 1" long fillet or flare bevel groove welds 1110-1140 while the assembly is in the horizontal position. Welds 1130, 1140 are on the inside of the "bottom" attachment portion 210d, as shown in the sectional view of Fig. 11C, and welds 1110, 1120 are on the outside of the "top" attachment portion 210d, as shown in Fig. 11A. Thus, a 20-panel joist would have 40 welds made to the

inside of the bottom attachment portion 210d, and 40 welds made to the outside of the top attachment portion 210d, of each of the two chords 200.

Likewise, as shown in Figs. 10C and 10D, seat members 1000 are rigidly assembled to a chord 200 such that the opposing side walls 1010 of seats 1000 abut the attachment portions 210d of chord 200 proximal to the opposed side walls 310 of web member 300. Seats 1000 are welded to chords 200 and web members 300 as described hereinabove, with approximately 1" long fillet or flare bevel groove welds 1040, 1050 while the assembly is in the horizontal position. Welds 1040 are on the outside of the top attachment portion 210d and side wall 310 (see Fig. 10C), and welds 1050 are inside of the bottom side wall 310 of web 300.

The present invention can be practiced by employing conventional materials, methodology and equipment. Accordingly, the details of such materials, equipment and methodology are not set forth herein in detail. In the previous descriptions, numerous specific details are set forth, such as specific materials, structures, chemicals, processes, etc., in order to provide a thorough understanding of the present invention. However, it should be recognized that the present invention can be practiced without resorting to the details specifically set forth. In other instances, well known processing structures have not been described in detail, in order not to unnecessarily obscure the present invention.

Only the preferred embodiment of the present invention and but a few examples of its versatility are shown and described in the present disclosure. It is to be understood that the present invention is capable of use in various other combinations and environments and is capable of changes or modifications within the scope of the inventive concept as expressed herein.